Health and Safety Executive
A report by HM Factory Inspectorate

The fire and explosion at Manro Products Ltd, Stalybridge
11 December 1982

REFERENCE ONLY
THIS BOOK MAY NOT BE
TAKEN OUT OF THE LIBRARY

HER MAJESTY'S STATIONERY OFFICE

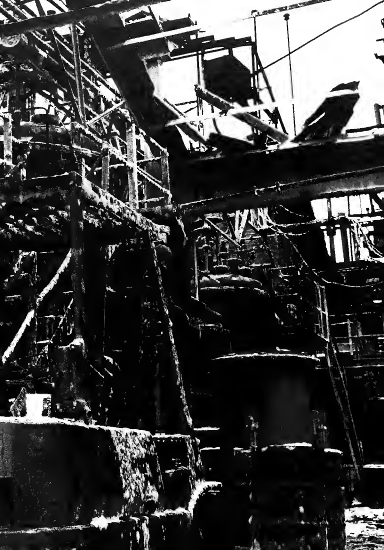
© *Crown copyright 1983*
First published 1983

Enquiries regarding the publication should be addressed to:
Area offices of the Health and Safety Executive, or
the general information and enquiry point,
Health and Safety Executive, St Hughs House,
Stanley Precinct, Trinity Road,
Bootle, Merseyside L20 3QY
Tel. 051 951 4000

ISBN 0 11 883715 X

Contents

Summary 5
History of the site and company 7
Description of plant, processes and chemicals stored 7
The fire and explosion 8
Injury and damage 9
Investigation 10
Legislation 10
Conclusions 11
Recommendations 12
Appendix 14
Map, site plans and diagrams



Summary

At approximately 10.15 hours on 11 December 1982 a fire followed by an explosion occurred in the factory of Manro Products Ltd at Bridge Street, Stalybridge, Greater Manchester. Fortunately no-one was injured and structural damage was confined to the site.

The prime cause of the incident was the absence of restraints which were essential in order to prevent excessive movement of glassware and a bellows connecting a reactor to a pair of condensers. Toluene vapour was discharged into the building in which this plant was situated when the glassware fractured. The Health and Safety Executive (HSE) consider that this breakage was most probably caused by pressure within the reactor forcing the unrestrained glassware upwards. The source of the ignition for the vapour was most likely an electrostatic discharge to earth from an insulated metal clamp on the glassware. Manro believe that excessive vibration from a nearby agitator was the cause of the breakage.

Although there are no new technical lessons to be learned from the incident, it nevertheless emphasises the importance of plant maintenance and the need for those concerned with this work to understand the significance of those components which may be of particular importance in operating the plant safely.

History of the site and company

1 Manro Products Limited occupy a site at Bridge Street, Stalybridge, (see site plan) which has been used for general industry since before the introduction of planning legislation in 1947. The Bridge Colour Company Limited had occupied the site for the manufacture of dyestuffs until the mid-1960s followed by Pfizer Limited, who manufactured various chemicals.

2 Manro commenced operations in premises at Brookbottom Mill in the nearby town of Mossley. Their first planning application relating to the Bridge Street site, for new office accommodation, was approved in 1971. Between then and 1980 there were 10 further planning applications for various developments consisting of the erection of chimneys, office extensions, laboratories, buildings for welfare amenities, bulk storage tanks and a spray drying tower. These resulted in an expansion over the whole of the site up to the Bridge Street boundary.

3 In granting these applications the planning authority imposed various conditions relating to pollution, noise levels, parking, effluent, drainage, construction materials and landscaping. They also required the provision of a monitoring point on a chimney.

4 In addition to the original site occupied by the Bridge Colour Company, Manro expanded onto a strip of land to the north west of Worthington Street, land bounded by the river, Bayley Street and the Dale Street extension, and at the rear of 14 to 34 Bayley Street.

5 The area has undergone numerous changes. Many streets of terraced houses originally occupied by workers in local textiles mills have been cleared; those mills which have not been demolished are used to house other industries. The area is now one of intense industrial usage with large tracts of recently cleared or virgin land offering potential for new industrial development.

6 The nearest housing to Manro was at 14/34 Bayley Street. These houses were about 70 metres from the organics shed and due for demolition, although number 18 was still occupied at the time of the incident. Other nearby occupied property was at Robinson Street/High Street, Kendal House at Grosvenor Street/High Street and the Booth Street Estate off Set Street (see Map). Distances from the organics shed at Manro were 285 metres, 200 metres and 275 metres respectively. The site of Hob Hill School immediately opposite Manro off High Street has been earmarked for residential development and this is 190 metres from the factory.

7 As Manro has expanded there have been many management changes and at the time of the fire and explosion the Managing Director, an experienced chemist who had been with Manro for over 10 years, headed a team which had a wide range of experience in the chemical industry both at Manro and elsewhere. The firm employed 64 people including clerical and sales staff, transport drivers and process workers. Eighteen of these employees worked on shifts.

Description of plant, processes and chemicals stored

Plant

8 The company had plant for the manufacture of two main products; chemicals for use in the foundry industry (mainly toluene sulphonic acid and xylene sulphonic acid) and detergents. The former were manufactured in batch reactors in that part of the site known as the organics shed, the detergents were manufactured in continuous reactors in the sulphonations shed (see site plan). In 1976 there were two batch and two continuous reactors; by 1982 these had increased to six and three reactors respectively.

9 The plant in the sulphonations shed was not involved in the incident and was not affected by it. After the fire and explosion the manufacture of detergents was able to continue normally.

10 In the organics shed there was a mezzanine floor 3.5 metres above ground level, constructed of rolled steel joists supported by steel columns with metal mesh flooring. This floor supported the reactors R1, R2, R3, R7 and R8 (see diagram 1). There was also a neutralising vessel N2 with a stirrer, a caustic soda solution holding vessel, two oleum measure vessels known as the shot tank and glass burette, a disused still and two centrifuges. Switchgear and control gear consisting of a group of nine push button starters were located in the south west corner of the shed at mezzanine level. Stairs adjacent to the centrifuges and at both sides of N2 provided egress from the mezzanine to the calpack store, the forecourt and the structure between the organics shed and the calpack shed.

11 Another reactor, R9, was supported on a steel structure 15 metres high and situated in the open air between the organics shed and the calpack shed.

12 All the plant in the organics shed was of similar construction and design. Reactor R2 (total volume 5,500 litres) and associated equipment is shown in diagram 2. The glass lined mild steel jacketed reactor was fitted with a viewing panel in the top, a stirrer, pipeline feeds for toluene, xylene and oleum, a pipe stub used for the addition of water, instruments giving indication of temperature and pressure/vacuum and a bursting disc rated at 55.2 kPa (8 p.s.i.) which with its associated vent line provided pressure relief to atmosphere. A run off valve at the bottom of the reactor and a pump were used to transfer product.

13 Borosilicate glass pipework, known as the vapour main, connected the top of the reactor to two

condensers with a solvent/water separator vessel below them also made of borosilicate glass. The vertical sections of the glassware were erected within tubular metal frameworks. Flanges attached to the glassware could be secured by means of four bolts (see diagram 3) to drilled angle iron sections which rested on the frameworks. Two bellows were built into the system between the reactor and condensers, one connected to the reactor (bellows A diagram 2) and the other connected to the top of the first condenser (bellows B). Each bellows, when properly fitted, would incorporate restraint provided by two limiting screws (see diagram 4) which would allow the bellows to expand and contract in the lineal direction between positions set by adjustable lock nuts on the screws.

14 The pair of condensers was provided with an atmospheric vent/vacuum line on the outlet side; this line incorporated a secondary condenser (see diagram 2). The vent at R1 had recently been extended and terminated outside the building; work was in hand to extend the vents for the condensers at R2, R3, R7 and R8.

15 The stirrer within the reactor R2 was driven through two vee belts and pulleys from an electric motor. No device was provided to detect movement of the stirrer; reliance was placed on frequent visual checks made by the plant operators and logged hourly.

16 Steam was supplied to the vessels by pipework from an oil fired boiler and this supply could be manually isolated by shutting the main steam valve located outside the calpack shed (see diagram 1). The cooling water required for the various items of plant was normally supplied from a pumped recirculation system located between the organics and calpack sheds. However, if the water pressure dropped for any reason an alarm would sound to alert the plant operators; piped town water would then automatically supply the recirculation pumps and a valve on the steam line to the organics shed would automatically close. All fixed electrical apparatus such as light fittings, motors, starters and socket outlets in the shed was selected for use in Zone 1 areas as defined in BS 5345.

Process

17 The manufacturing processes for toluene sulphonic acid and xylene sulphonic acid were similar. Addition of oleum (100% sulphuric acid containing dissolved sulphur trioxide) to toluene forms toluene sulphonic acid, sulphuric acid and water. Reactor R2 with its associated equipment was one of the vessels used to carry out this process (see diagram 2).

18 The reactor contents are cooled during the controlled oleum addition since the reaction is rapid and vigorous with liberation of considerable heat. The reaction is completed by removing the water that is formed. This is achieved by having more toluene present than the sulphuric acid needs for complete conversion and by distilling the toluene/water mixture. The condensed toluene/water mixture is collected in the separator, the toluene being returned to the reactor (see diagram 2). The removal of sufficient water to allow the reaction to be completed takes several hours and during this time the temperature, volume of water separated, steam pressure at the reactor jacket, and stirrer motion is checked visually and logged at hourly intervals. For the purposes of quality control the upper temperature limit of the vessel contents is normally 120°C. Higher temperatures indicate that too little toluene is present; if the temperature exceeded 120°C, the reactor contents would be cooled and a further measured amount of toluene added. The distillation would be restarted to complete the reaction. At the end of the reaction, the excess toluene would be separated from the toluene sulphonic acid.

Chemicals

19 Liquid sulphur trioxide was stored in two, 40 tonne capacity mild steel tanks specifically designed and fabricated for this use and located in a specially constructed building adjacent to the sulphonations shed; approximately 35 tonnes were in store at any one time. Outside the end wall of the sulphonations shed some 16 metres from the River Tame there were five mild steel storage tanks (see site plan). One held ammonia solution (36,000 litres) and stood in its own bund; two held methylated spirits (15,300 litres and 27,000 litres) standing in another bund; two stored methyl ester of coconut oil and a mixture of predominantly glycerol with a small methanol content (27,000 litres and 13,500 litres). There was also storage of up to twenty 200 litre drums of methanol on the concrete pad adjacent to the bunds

20 Liquid raw materials used in the sulphonations shed together with sodium hydroxide solution (none of which were highly flammable liquids or significantly toxic) were kept in bulk storage tanks as were the final products (see site plan).

21 There was bulk storage of chlorobenzene (18,000 litres), toluene (54,000 litres in two tanks) and xylene (27,000 litres) in vertical mild steel tanks in a bunded area adjacent to the organics shed and the calpack store. The tanks adjacent to the forecourt were 15 metres from the boundary with Bridge Street. Up to 22,500 litres of oleum could be stored in the separately bunded mild steel horizontal storage tank in the same area.

22 Vessels H1 to H7 were used to store finished and intermediate products from the organics shed (see diagram 1). The caustic soda solution storage tank in the shed was only used when neutralisation was to be carried out in N2.

The fire and explosion

23 During November 1982 the cooling coil in one of the two glass condensers at R1 had failed and a new

condenser was installed by a specialist glass erector and a Manro fitter. This practice had frequently been followed in the past when such glassware had been rebuilt. The condenser with the damaged coil was sent for repair and was returned to Manro at the end of November. On Friday 3 December the cooling coil in the upper condenser at R2 failed and the process was shut down. Similar failures had been experienced before but these did not result in any loss of containment of vapour and did not create a hazard.

24 On Monday 6 December three fitters employed by Manro replaced the damaged condenser at R2 with that recently repaired (see para 23). Fibre rope and tackle were used to lower the top section and damaged cooling coils and then to lift the replacement condenser and the top section into place. Water in the reactor was boiled to simulate normal operating conditions and 220 litres were distilled without any apparent problems; later that night one of the fitters was called from home to deal with a minor leak at the bottom of the condenser unit. R2 was subsequently used, without incident, to manufacture two batches, the second batch being toluene sulphonic acid made in the manner previously described.

25 At about 0500 on 11 December 1982 the production of another batch of toluene sulphonic acid was started in R2 by operators on the night shift. At 0700 the night shift was relieved by the day shift which consisted of an experienced foreman and an operator. The foreman was advised of the state of the plant. By this time the initial reaction in R2 was complete and the distillation stage was just starting (see para 18), steam having been admitted to the reactor jacket to raise the temperature of the contents. Vessels R1, R3, R7, R9 and N2 were also in use.

26 At 0730 the valve on the line between the solvent/water separator and R2 was opened to allow toluene to return to R2 (see para 18). The foreman noted that the temperature of the reactor contents was 108°C, the steam pressure to the jacket was 414 kPa (60 p.s.i.) the pressure in the vapour space atmospheric and the stirrer in motion.

27 At about 0830 he went to R2 and saw that the temperature was 120°C, slightly higher than expected at this stage (normally between 112°C and 116°C), so he decided to check the system further. The level of the reactor contents appeared normal, the steam pressure to the jacket was 345 kPa (50 p.s.i.) the stirrer was in motion and the vessel pressure still atmospheric.

28 Shortly after 1000 hours the foreman checked the temperature gauge at R2 and noted that it indicated 122°C; the level of the contents, the vessel pressure and steam pressure were normal. He decided that more toluene had to be added (see para 18); he shut off the steam supply to the jacket to allow the contents to cool while he carried out other work in the shed. He went onto the mezzanine where the switch boxes were located (see para 10) and as he depressed a switch to start the agitator at N2 he heard a loud crash to his left. He moved away from the switch area and saw white fumes 'billowing' out of the glassware connecting R2 to the condenser (see diagram 2). The fumes fell rapidly, enveloping the area below and he ran down the stairs to the forecourt.

29 The day shift operator had been standing at the centrifuge when he heard a very loud cracking noise to his left. He glanced round and saw the horizontal glass pipe interconnecting the vertical leg of the vapour main to the top of the condenser column at R2 falling as though hinged about the joint at the top of the vapour main (see diagram 2). White fumes came pouring out with a rushing noise like steam out of a burst pipe; the fumes spread and seemed to fill the shed. He shouted to the foreman and then as he turned to run down the steps he heard a noise behind him. He ran into the calpack shed and operated the fire alarm on his way out. The atmosphere in this shed was clear but the fumes were drifting into the calpack store.

30 In the meantime the foreman had re-entered the organics shed, run between H1 and H2 where the fumes were not so dense, and met the operator in the calpack shed. Both men went outside where the foreman closed the main steam valve for the organics shed; they then re-entered the calpack shed to turn off the vacuum pump (see diagram 1). They looked up at the windows forming part of the partition between the calpack shed and the open air structure and saw either a fireball or reflections of fire. They walked to H5 and as they looked closer in towards the organics shed they saw a very large fireball and decided to leave the building as quickly as possible. They turned to run through the open doorway adjacent to H7 when there was an explosion which blew them towards the doorway. This explosion shattered roof and side panels and caused a fireball to rise approximately 20 metres.

31 The time that had elapsed between the cracking of the glassware at R2 and the explosion was estimated to be less than two minutes. The explosion was followed by two small fires within the organics shed. The fire brigade arrived very soon after the explosion, having heard it at their fire station nearby.

Injury and damage

32 The two men who were working in the organics shed escaped injury and structural damage was confined to the buildings and plant on the site (see site plan).

33 The fragile corrugated roofing and side panels of the organics shed had disintegrated as would be expected. However, this had the advantage of venting the force of the explosion and no doubt assisted in preventing more extensive structural damage to the buildings. Nevertheless, the windows and roofing panels of the calpack store had been blown out and

some brick work displaced; several windows at the front and rear of the two storey office block (Bridge House) were also broken. The two portable cabins on the forecourt outside the organics shed were damaged by the fire; apart from some glassware and light fittings all the reactors and tanks in the organics shed suffered superficial damage only. The storage tanks containing chlorobenzene, toluene, xylene and oleum were not affected.

Investigation

34 Information about the incident was received from the fire brigade at approximately 1200 hours and the Principal Inspector of Factories for the chemicals group covering Greater Manchester, accompanied by another inspector, arrived at the factory at approximately 1240 hours. The damage to the organics shed and nearby buildings on the site was examined and arrangements made to interview the two employees who had been working in the shed. It was noted that the process records had been destroyed by the fire. The detailed investigation began on Monday 13 December and extended over a lengthy period. Inspectors from the Greater Manchester area were joined by specialist inspectors from the North West Field Consultant Group and Factory Inspectorate headquarters and from the Health and Safety Executive Research and Laboratory Services Division.

35 During the course of the investigation it was noted that at bellows A (see diagram 2) the required limiting screws were missing (see para 13), some of the convolutions were distended and the bellows flanges were misaligned (see photograph page 12); the distance between these flanges varied between 18mm and 28mm. Trade literature held by Manro indicated that this distance should be 65mm. At bellows B the limiting screws were fitted but had been bent; no other damage to these bellows was evident. It was also noted that three of the bolts provided to secure the vapour main to the angle irons on the framework (see para 13) were not secured because the nuts were missing. On the fourth bolt the nut was so slack as to be ineffective (see diagram 3). Similarly there were no anchors, guides or other supports to restrain adequately the bend at the top of the vertical section of the vapour main. The bursting disc on the reactor had ruptured and the PVC vent line fixed to the mild steel section was charred and had collapsed. There was a very thin coating of soot on the inside glass walls of the reactor R2. All the valves on the pipes leading into R2 appeared to be in a position consistent with the state of the process that had been reached. Analysis of samples of the contents of the reactor indicated that 300 kilograms of toluene had been lost from the reactor and that the ratio of toluene sulphonic acid to free sulphuric acid was as expected at this stage of the reaction.

36 The agitator shaft at N2 had a lower PTFE bearing mounted in a stainless steel support at the base of the vessel. The nominal size of this bearing was 50mm. When removed from the reactor it was seen to have been eccentrically worn by 12mm. This wear was attributed to the misalignment of the top and bottom bearings. There was no evidence of significant wear at the top bearing which was external to the reactor. The three legged agitator blade was loose on the shaft. Tack welds which had been used to secure the blades to the shaft had failed and the single locating grub screw had worn a groove in the shaft sufficient to allow a limited amount of radial movement.

37 About 60 items of electrical equipment and associated cables were subjected to detailed examination which showed that some of them had not been correctly installed and maintained. Examples included missing or loose flange studs, spare cable entry holes in flameproof enclosures not blanked off, some cable glands not suitable for the cable used and in one case cable not suitable for classified areas used in conjunction with a flameproof fitting. However, there was no conclusive evidence to show that any of these defects had provided the source of ignition (see para 53). Some electrical controls were found not to be labelled to indicate their function but the extent to which labelling was damaged by the fire was difficult to assess.

38 In view of the insulating properties of toluene the foreseeability of electrostatic ignition of the toluene vapour was considered. The investigation included experimental work to determine a possible source of static electricity and therefore charging and to identify metal or other conducting objects which may have been sufficiently insulated from earth to have been able to become charged to a potential capable of igniting the toluene vapour.

39 Examination revealed a large number of metal clamps and also a few metal valves which were insulated from earth by glassware. Testing on site was not practicable because plant was wet and dirty having been exposed to the weather as a result of the explosion. However, some items of plant were removed, cleaned and dried and tested under laboratory conditions. It was found that when the glassware was moderately clean and dry its electrical resistance was such that it would allow metal objects fastened to it to become charged and these would remain charged for prolonged periods.

40 It was considered likely that such metal parts exposed to a source of electrostatic charging from a leak either of steam or escaping toluene vapour became charged, sparked over to an earthed object and ignited the toluene vapour/air mixture.

Legislation

41 The premises occupied by Manro were subject to the Health and Safety at Work etc Act 1974, constituted a factory as defined in the Factories Act

1961 and a Written Notice of Occupation was received by the Inspectorate on 28 April 1972 in compliance with Section 137 of the Factories Act. The premises were subject to inspection by the Inspectorate and the last inspection was made in July 1981. An inspection was planned before the end of 1982 but was preceded by the fire and explosion.

42 Section 2(1) of the Health and Safety at Work etc Act 1974 imposes a duty on an employer to ensure, so far as is reasonably practicable, the health, safety and welfare at work of all his employees. This duty extends to include:

(a) The provision and maintenance of plant and systems of work that are, so far as is reasonably practicable, safe and without risks to health and
(b) The provision of such information, instruction, training and supervision as is necessary so far as is reasonably practicable to ensure the health and safety at work of his employees.

43 There is no clear evidence to suggest that the standards to which the chemical plant was originally designed and constructed were in any way unsuitable. However, such plant has to be maintained and the investigation showed that the bellows mounted immediately above the reactor and below the vapour main leading to the condenser was not properly assembled as the limiting screws intended to restrain movement were not fitted. Those who carried out maintenance on the bellows did not appear to appreciate the function or importance of these screws and they had apparently been omitted as a result of this lack of knowledge. In addition, the glassware was not properly supported and restrained to prevent movement (see para 35).

44 The Health and Safety Executive therefore concluded that Manro had not fulfilled the duty imposed by Section 2(1) and legal proceedings were instituted by the Executive; the case was heard summarily before the Magistrates' sitting at Dukinfield Magistrates' Court and a fine of £250 was imposed.

45 A review of other legislation that applied to the premises is contained in the appendix.

Conclusions

46 The primary cause of this incident was the absence of restraints which were essential in order to prevent excessive movement of glassware and a bellows connecting the reactor to the condensers. Toluene vapour was discharged into the organics shed when the glassware fractured at the junction between the vapour main and the top section above the condenser (see diagram 2).

47 It is the opinion of the Health and Safety Executive that this breakage was most probably caused by pressure within the reactor forcing the unrestrained bellows and vapour main upwards; it is considered that the damage to bellows A (see para 35 and photograph) could only have been caused in this way.

48 The vapour main was connected to the reactor via unrestrained bellows and was not prevented from moving vertically by any other restraint. Therefore when the internal pressure exerted sufficient force to overcome the weight of the vapour main plus the relatively minor force required to extend the bellows, the vertical leg of the vapour main would begin to lift. Calculations indicate that for this to occur the pressure necessary would be 20.7 k P a (3 p.s.i.) and at 41.4 k P a (6 p.s.i.) stress at the interchange of section at the condenser cap would approach the theoretical fracture point.

49 The vapour main could therefore begin to lift before the pressure was sufficient to rupture the bursting disc (designed to relieve at 55.2 k P a–8 p.s.i.). Although the disc did rupture it is not certain when this occurred; however, if it failed before the glassware the shock load associated with rupture of the disc may have contributed to the breakage of the glassware.

50 When the vapour main lifted, the horizontal section would exert a bending moment where it joined the shell precisely where the first fracture is known to have occurred, releasing the vapour into the organics shed (see paras 28 and 29). The bellows fitted at this point (bellows B see diagram 2), unlike those fitted between the reactor and vapour main, had the limiting screws in position making a comparatively rigid joint. Examination of the bellows after the incident showed the limiting screws were bent which further supports the contention that leverage was applied at this point.

51 The cause of the pressure could not be established from the available evidence. However, pressure rise during this reaction is foreseeable and could be caused in a number of ways. These include insufficient cooling or stirrer failure followed by sudden re-starting at a critical stage in the reaction. Although precautions had been taken to prevent insufficient cooling (see para 16) reliance on visual monitoring of stirrer rotation (see para 18) is inadequate for this type of reaction. Automatic monitoring with provision of a suitable alarm to warn operators of malfunction is necessary.

52 An alternative explanation, put forward by Manro, is that excessive vibration resulting from the starting of the agitator at N2 (see paras 28 and 36) was transmitted through the mezzanine and caused the glassware to crack and subsequently break. They think that the damage to bellows A (see para 35) resulted from a sideways displacement of the vapour main caused by the explosion which also created suction within R2 and ruptured the bursting disc.

53 There were several potential sources of ignition. It was considered most likely that the first source was an electrostatic discharge to earth from an insulated metal clamp on the glassware; the subsequent sources of ignition could have been electrical equipment eg a

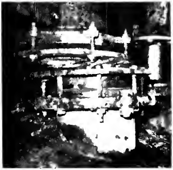
shattered light fitting, but once a fire had started, subsequent ignitions were, in any case, inevitable.

54 The potential consequences of this incident were no doubt minimised by the storage of hazardous materials in safe positions in the open air (see paras 20–21) and the materials used in the construction of the organics shed (see para 33).

Recommendations

55 No new technical lessons were learned from this incident which, nevertheless, underlines the need for:

(a) all plant and equipment to be installed in accordance with the designers' and manufacturers' instructions and then inspected and maintained to that standard;
(b) staff engaged on maintenance to receive adequate training and have their attention directed to any components which are particularly important if the plant is to be operated safely;
(c) earthing of metalwork close to valves, pipe-joints etc on glass or other insulated pipework to prevent the accumulation of a static charge.



"Some of the convolutions were distended and the bellows flanges were misaligned" (see para 35).

Appendix

A review of other legislation that applied to the premises

1 The separate office block, Bridge House, was subject to the Offices, Shops and Railway Premises Act 1963; the company had given notification to the Factory Inspectorate on 26 January 1972 in accordance with Section 49 of the Act.

2 The premises were subject to regulations made under the Factories Act namely the Electricity (Factories Act) Special Regulations 1908, the Highly Flammable Liquids and Liquefied Petroleum Gases Regulations 1972 and the Chemical Works Regulations 1922.

3 Regulation 27 of the Electricity (Factories Act) Special Regulations 1908 requires that all electrical conductors and apparatus exposed to inflammable surroundings or explosive atmospheres should be so constructed as may be necessary adequately to prevent danger. The occupier had designated the organics shed as a Zone 1 area, defined in BS 5345 as being a hazardous area in which an explosive gas/air mixture is likely to occur in normal operation. In such areas special precautions for the construction and use of electrical conductors and apparatus are necessary. Examination of pumps, switch boxes and light fittings indicated that such apparatus was originally constructed to be suitable for use in Zone 1 areas; however a conductor namely a cable to one of the light fittings was not suitable (see para 37).

4 There is also a requirement, as part of the duties imposed by Regulation 1 of the 1908 Regulations to install and maintain all conductors and apparatus so as to prevent danger so far as is reasonably practicable. Examination of about 60 items of electrical equipment and associated cables indicated that on some of these this standard had not been achieved (see para 37).

5 The Highly Flammable Liquids and Liquefied Petroleum Gases Regulations 1972 define a highly flammable liquid as being one which, when tested in the manner described in the schedules to these Regulations, has a flashpoint of less than 32°C and supports combustion.

6 Regulation 5 refers to the storage of highly flammable liquids but the regulation does not apply where the highly flammable liquids are petroleum spirit as defined in the Petroleum (Consolidation) Act 1928 and which are authorised to be kept by a licence in force under that Act (see Appendix, para 18).

7 Regulation 8 deals with precautions against spillage and leaks and requires where it is reasonably practicable to do so, highly flammable liquids to be conveyed through a totally enclosed system incorporating pipelines and pumps. The reaction vessel R2 was charged by means of a totally enclosed system as were the other vessels in the plant. The regulation also requires that such a system should, so far as is practicable, be so designed, constructed, installed, placed and maintained as to avoid leakage. There was no evidence that leakage of liquid was responsible for the incident.

8 Regulation 9 deals with sources of ignition and applies to the situation where a dangerous concentration of vapours from highly flammable liquids may reasonably be expected to be present. For the purposes of the regulation the term 'dangerous concentration of vapours' means a concentration greater than the lower flammable limit of the vapour which, in the case of toluene, is greater than 1.3%. In a totally enclosed system concentrations of this order would not be expected except in very localised positions in the vicinity of pumps, glands, bearings etc. However, as indicated in para 16 the entire area of the organics shed had been treated as Zone 1 in relation to electrical apparatus.

9 Regulation 10 refers to the prevention of the escape of vapours and the dispersal of dangerous concentrations. Each of the condenser systems in the organics shed had an atmospheric vent line on the outlet side. The vent at R1 had been extended and terminated outside the building; work was already in hand to extend the vents on the other condensers which, at the time of the fire and explosion, terminated inside the building. However, the escape of vapours was not from the condenser vent line on R2 but was undoubtedly due to the fracture of the chemical glassware which made up the condenser assembly. The glassware was designed for the purpose for which it was being used and would be considered as being effective in preventing the escape of vapours into the working area. Such minor leakages as might be expected to occur at joints, flanges etc, throughout the plant would quickly be dispersed by the natural ventilation of the organics shed.

10 The Chemical Works Regulations 1922 applied to the factory. Regulation 4 deals with sources of ignition and contains similar requirements to those contained in Regulation 9 of the Highly Flammable Liquids and Liquefied Petroleum Gases Regulations. Regulation 5 requires means for relieving dangerous pressures in closed vessels. A bursting disc had been fitted to the reaction vessel with its vent line to atmosphere (see para 12).

11 Section 2(3) of the Health and Safety at Work etc Act 1974 requires the employer to prepare a written statement of his general policy with respect to the health and safety at work of his employees and the organisation and arrangements for carrying out that policy. The company had produced a handbook of terms and conditions of service of its staff. This included a safety policy statement with details of the duties and responsibilities of staff, safety training and the organisation of the safety committee. For the process involved in the fire and explosion a comprehensive set of written instructions had been drawn up which gave the operator clear details of every step in the operational procedure.

12 Section 3(1) of the Act places a duty on the employer to conduct his undertaking in such a way as to ensure so far as is reasonably practicable that persons not in his employment, such as members of the public, are not exposed to risks to their health and safety. The effects of a fire or explosion within the plant included the likelihood of injury, both to employees and to members of the public, namely residents or persons passing by. Consequently the precautions that were necessary to secure safe operation of the plant had a dual role to protect both employees and the public.

13 Section 6 of the 1974 Act places a duty on any person who designs, manufactures, imports or supplies any article for use at work (which would include the bellows) to take such steps as are necessary to secure that there will be available, in connection with the article at work, adequate information about the use for which it is designed and has been tested, and about any conditions necessary to ensure that when put to that use it will be safe and without risks to health. Information about the purpose of the limiting screws in the bellows was contained in a trade catalogue held by Manro.

14 A further duty is imposed by Section 6(3) on any person who installs any article for use at work on any premises where that article is to be used by a person at work to ensure so far as is reasonably practicable that nothing about the way it is erected or installed makes it unsafe when properly used. A specialist company erected the bellows and vapour main in 1980; there was no evidence to suggest that this installation work was in any way defective.

15 The fire and explosion did not result in any notifiable injury but because it resulted in the stoppage of the plant for more than 24 hours and was due to the ignition of processed materials, it was notifiable as a dangerous occurrence in accordance with the Notification of Accidents and Dangerous Occurrences Regulations 1980, and a notification was received.

16 By virtue of the storage of sulphur trioxide notification of the installation to the Health and Safety Executive is required under the Notification of Installations Handling Hazardous Substances Regulations 1982 in force from 1 January 1983; a notification has been received.

17 The premises were registered under the Alkali etc Works Regulations Act 1906 and subject to inspection by HM Industrial Air Pollution Inspectorate of the Health and Safety Executive for the purposes of that Act.

18 The storage of petroleum based solvents was subject to the Petroleum (Consolidation) Act 1928 administered by the Greater Manchester Council and licences had been issued.

19 The premises were subject to the Fire Precautions Act 1971. Fire certificates had been issued by the fire authority and information about the site had been obtained by the fire brigade using their powers under the Fire Services Act 1947.

Printed in the UK for HMSO
Dd 715345 C25 11/83